DX magnets and interaction regions aperture studies

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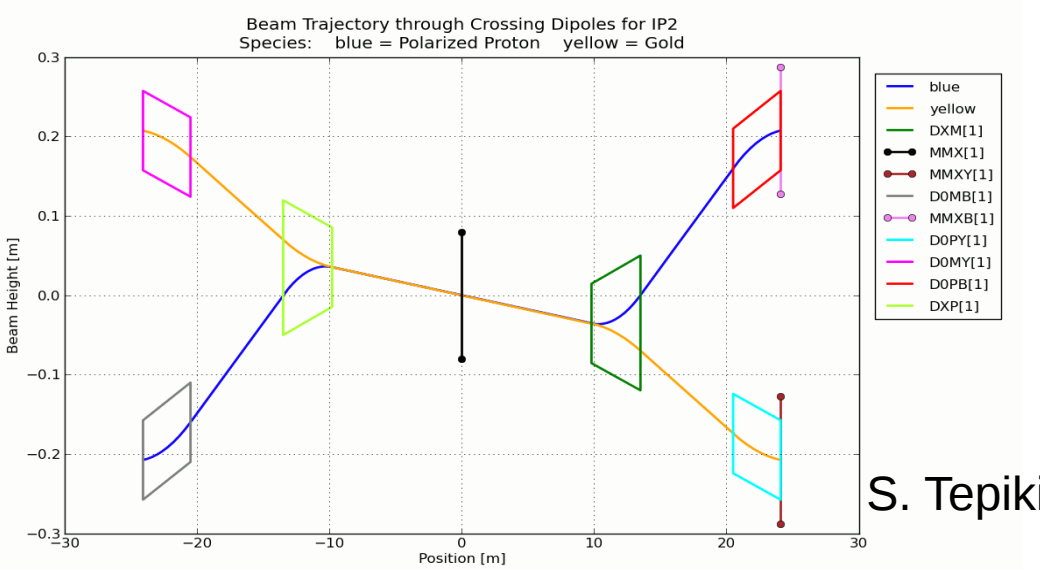
APEX workshop, BNL

Outline

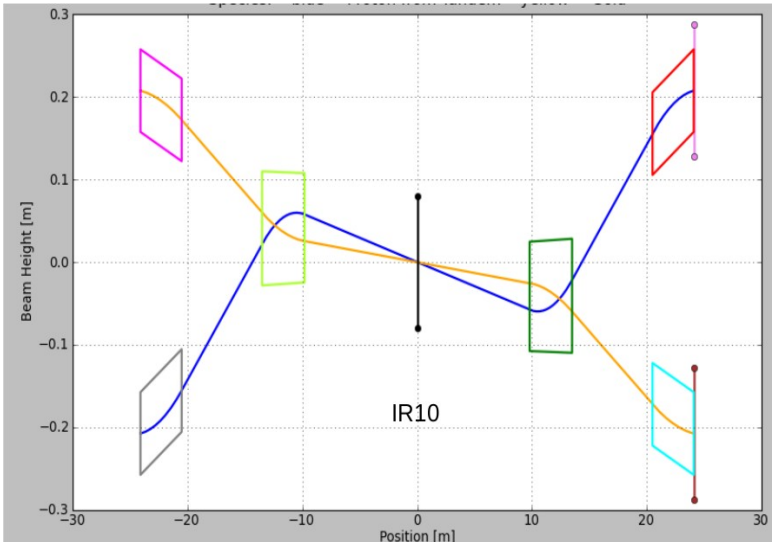
- Motivation
- Past experiments
- Future work

Motivation



S. Tepikian

Beam trajectories at IR6 & 8 for p-A run



Beam trajectories at non-colliding IR for p-A run

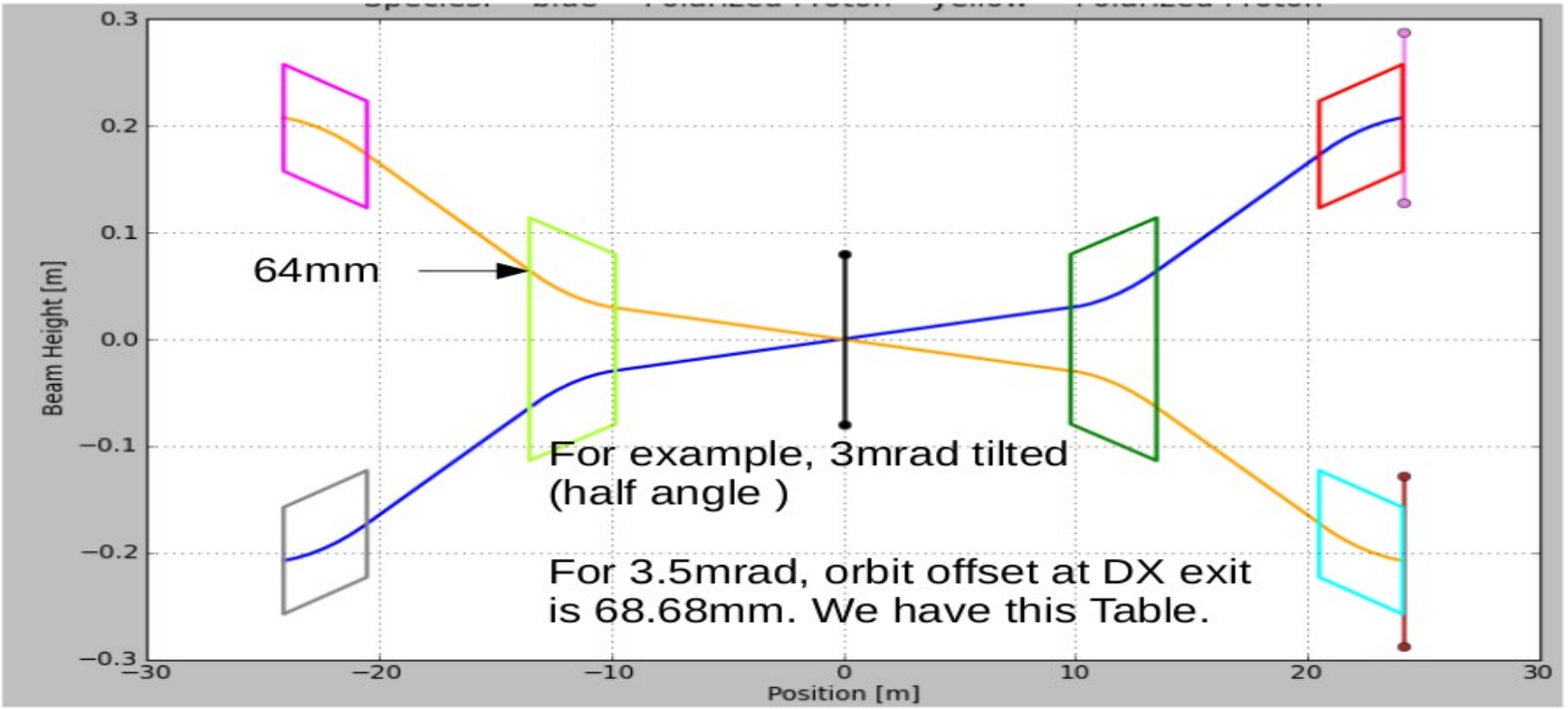
In preparation of p-A run, one need to answer these questions:

- Are DX apertures same as claimed? Symmetric?
- How much DX needs to be moved?
- Is there anything else in the way?

Experimental plan

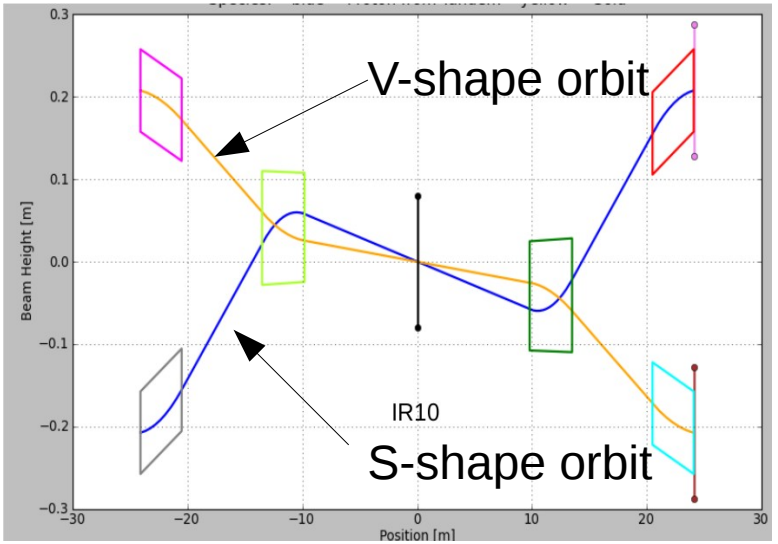
Yun established the right “angle scan” experimental plan in APEX workshop 2013.

1) Calculate settings of DX and D0 for a tilt angle or a known orbit offset at DX exit.
2) Set these strengths into machine and measure the beam decay.
3) Increase the angle until a huge beam loss is observed.
4) Determine the minimum distance between the beam center and the pipe wall offline.



Supplement to the experimental plan

- S-shape orbit, orbit of blue beam, has a larger angle (4.8 mrad) at non-collision IRs. It's more likely the aperture limit is between DX magnets.
- V-shape orbit, orbit of yellow beam, has a larger orbit excursion at the exit of DX magnets and more likely to scrape there.
- A “s-shape orbit” angle scan is critical for aperture limit in the IRs between DX magnets. To do that, the D0 shunt supplies polarity needs to be flipped.



Results in 2014

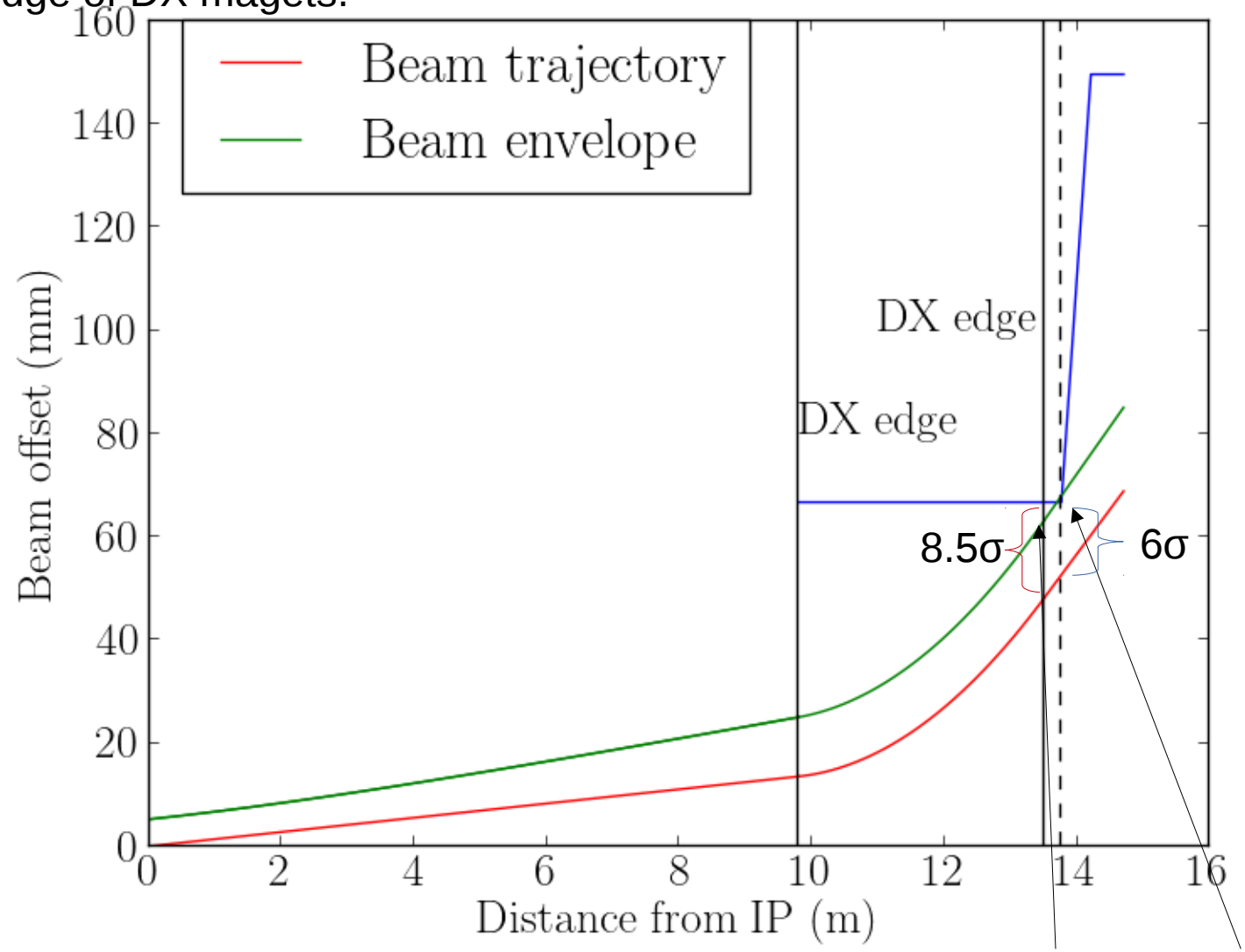
IR	DX Max Current (A)	DX Min Current (A)	Blue Loss begin (A)	Yellow Loss Begin (A)	Orbit Angle w.r.t. axis (mrad)
IR8	146.66	35.10	97		1.45
				98	1.42
IR6	148.37	36.69	98		1.47
				101	1.38
IR2	148.87	37.12	93		1.62
				97	1.51

Late slide on STAR beam pipe

The conclusion was beam center needs to be 8.5 sigma away from the wall otherwise beam loss happens.

A explanation of the angle scan result

To calculate how much space we need, it's important to know exactly where the aperture limit is. The vacuum chamber extends < 1' from the edge of DX magets.



Beam didn't scrape here, but there

STAR beam pipe

IP6 with Star and NEG coated pipes

IP6-05
09/20/12

+ IN X = INBOARD
− IN X = OUT
+ IN Y = LOW
− IN Y = HI

Component	Part No.	Distance to IP		Part Length		Flange OD	Pipe ID	X	Y
		(m)	(inch)	(inch)	(cm)	(inch)	(cm)		
#5 DX flange		8.615	339.15						
Gate Valve	43035007-2	8.615	339.15	3.84	9.75	6.75	12		
BPM-4	81015132	8.517	335.32	15.00	38.10	6.75	12	+.226	.160
Bellows-I	43035004-3	8.136	320.32	15.38	39.05	6.75	12		
Pump Tee	43015011	7.746	304.94	13.12	33.32	6.75	12		
Bellows-I	43035004-1	7.412	291.82	10.62	26.97	6.75	12		
5" Pipe w/ transition - NEG	44035003	7.143	281.20	79.83	202.77	6.75-4.62	12-7	+.382	.243
C-B Bellows	42035000-3	5.115	201.37	12.37	31.42	4.62	7		
3" Al Pipe-NEG	44035023	4.801	189.00	30.00	76.20	4.62	7	+.109	.380
3"Al Pipe w/ transition-NEG	44035022	4.039	159.00	103.29	262.36	4.62-2.75	7.0-4		
Al section-NEG	44035019	1.415	55.71	39.96	101.50	4.62	4	+.273	.128
Be section-NEG	44035019	0.400	15.75	15.75	40.01		4		
IP6		0.000	0.00						
Be section-NEG	44035019	0.800	31.50	31.50	80.01		4		
Al section-NEG	44035019	1.415	55.72	24.22	61.52	4.62	4		
3"Al Pipe w/ transition-NEG	44035021	2.800	110.25	54.53	138.50	2.75-4.62	4-7.0		
3" Al Pipe-NEG	44035020	4.039	159.01	48.76	123.86	4.62	7	+.098	.002
C-B Bellows	42035000-3	4.353	171.38	12.37	31.42	4.62	7		
5" Pipe w/ transition - NEG	44035003	7.143	281.21	109.83	278.96	4.62-6.75	7-12		
5" Pipe	43035019	7.412	291.83	10.62	26.97	6.75	12		
Bellows-I	43035004-3	7.803	307.20	15.38	39.05	6.75	12		
BPM-4	81015132	8.184	322.20	15.00	38.10	6.75	12		
Pump Tee	43015011	8.517	335.32	13.12	33.32	6.75	12		
Gate Valve	43035007-2	8.615	339.16	3.84	9.75	6.75	12		
#6 DX flange		8.615	339.16						

SURVEYED PRESENT POSITION

X moved to "0

Results in 2015

Yellow ring

IR	DX PS current (A)	Tilt Angle Range (mrad)	Sharp Loss PS Current (A)	Aperture of Tilt Angle (mrad)
IR4	168.9-->311.6	-1.5--> -10mrad	205.0	-3.64
IR2	178.6-->313.1	-2-->-10mrad	228.2	-4.95
IR12	145.7-->44.4	0-->6mrad	86.1	3.52
IR10	142.9-->42.6	0-->6mrad	89.7	3.18
IR8	143.9-->43.0	0-->6mrad	97.5	2.76
IR6	144.6-->43.8	0-->6mrad	98.0	2.78

Blue ring

IR	DX PS current (A)	Tilt Angle Range (mrad)	Sharp Loss PS Current (A)	Aperture of Tilt Angle (mrad)
IR4	284.89--> >345.28	-8.4--> -12mrad	307.61	-9.75
IR2	306.388--> >397.23	-9.6-->-15mrad	309.343	-9.77
IR12	145.7-->61.3	0-->5mrad	83.55	3.68
IR10	143-->59.4	0-->5mrad	74.7	4
IR8	144.704-->60	0-->5mrad	99.6	2.66
IR6	144.704--> >60.566	0-->5mrad	101.5	2.56

-8.4 is sufficien

-9.6 is required

A survey was done later at IR2 finding that the ion pump was off by 13 mm horizontally.

List of components

- Before Run-15.
  - DX magnets at IR2&4 moved.
  - 9 MHz
  - AC dipole at IR4 removed.
  - STAR beam pipe
  - IR2 ion pump
- During switch-over.
  - Magnets: DX magnets at IR6, 8, 10, 12.
  - Non-magnetic: DX radiation shields at sector 7 and 8, DX-D0 chambers at sector 5, 6 and 8 (radial shift), DX-D0 chamber at sector 7 (rotation, DX end goes with DX magnet), ZDCs at sector 5, 6, 7 and 8

Aperture related beam loss during p-A run

- On Apr. 28 both proton and Au beams circulated in RHIC.
- Orbit oscillation of Au beam at transition emerged as a problem during setup. Beam scraped at IR4. The problem was solved by reducing yellow beam angle at injection which was allowed since there was no blue beam in the ring yet.
- In the middle of the run, beam angles were equalized at IR10 to reduce the loss of blue beam at location of e-lens.

Summary and future work

- DX magnets apertures were symmetric and large enough for a p-Au run. The magnets are stable in position since first installed.

- Unexpected aperture limits are in-between DX magnets, where beam elements are light weight and often touched over the course.

- For a future A-p run, the pant leg bellows needs to be changed to allow for movement. IR components need to be surveyed. Beam studies need to be revisited.